rates up to 30 kelvin per day) drives a local updraft and lofts the contrail core several hundred meters. The observed rate of contrail spreading and maintenance of optical depths larger than 0.1 can be explained simply by the growth and precipitation of ice crystals that nucleate during the initial contrail formation if the environmental humidity is high enough (relative humidity with respect to ice greater than 125%). This result is consistent with the high humidities observed in regions where the persistent contrails formed on May 12. Also, the simulations indicate that the humidity must be high throughout a depth of at least several hundred meters below the contrail to allow the crystals to continue growing as they fall.

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The Roles of Aerosols in Stratospheric Ozone Chemistry

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Stratospheric aerosol can affect the environment in three ways. Sulfuric acid aerosols have been shown to act as sites for the reduction of reactive nitrogen and chlorine and as condensation sites to form (under very cold conditions) polar stratospheric clouds, which facilitate ozone depletion. Recently, modeling studies have suggested a link between black carbon aerosol (BCA) and ozone chemistry. These studies suggest that nitric acid (HNO_3), nitrogen dioxide (NO_2), and ozone (O_3) may be reduced heterogeneously on BCA particles. The ozone reaction converts ozone to oxygen molecules, while HNO_3 and NO_2 react to form nitrogen oxide (NO_x). Finally, a buildup of BCA could reduce the single-scatter albedo of aerosol below a value of 0.98, a critical value that has been postulated to change the effect of stratospheric aerosol from cooling to warming. Correlations between measured BCA amounts and aircraft use have been reported. Attempts to link BCA to ozone chemistry and other stratospheric processes have been hindered by questions concerning the amount of BCA that exists in the stratosphere, the magnitude of reaction probabilities, and the scarcity of BCA measurements.

Recently the Cloud and Microphysics Group participated in the NASA-sponsored Photochemistry of Ozone Loss in the Arctic Region in Summer (POLARIS) mission, which studied ozone depletion mechanisms in the Arctic summer and was completed in Alaska in 1997. The Ames Wire Impactors (AWI) were used in this mission as part of the complement of experiments on the NASA ER-2 aircraft, with the objective of measuring the character of the stratospheric aerosol during POLARIS and providing this information to the scientific community. A main objective of the study was to determine the amount of aerosol surface area, particularly that of BCA, available for reaction with stratospheric constituents and to assess, if possible, the importance of these reactions. The AWI collect aerosol and BCA particles on thin palladium wires that are exposed to the ambient air in a controlled manner. The samples are returned to the laboratory for subsequent analysis. The product of the AWI analysis is the size, surface area, and volume distributions, and the morphology and elemental composition of the aerosols and BCA. Modifications to the AWI data analysis procedures were required in which the collection of BCA is modeled as a fractal aggregate. The new analysis results in an increase in BCA surface area of approximately 24 and an increase in mass of 10 from the previous method. The character of the BCA and its area distributions measured during POLARIS are compared with those made by the AWI on past missions; the comparisons show trends in the spatial and temporal distribution. One trend confirms that the amount of BCA in the Northern Hemisphere is much greater than in the Southern Hemisphere. For the current study, BCA surface area is used in computer models that attempt to predict measured nitrogen oxide/reactive nitrogen (NO_x/NO_y) ratios.

Preliminary analysis attempts to relate BCA surface area to the nitrogen cycle of ozone chemistry. Inclusion of the HNO_3 reaction with BCA in one model improves the agreement of calculated to measured NO_x/NO_y ratios, but more work is yet to be done. The effect of the other reactions on the ratio needs to be explored. An assessment of the accuracy of the reaction probabilities should be made, if possible. Radiative effect must also be evaluated.

Katja Drdla of the National Research Council, Ross J. Salawitch of Jet Propulsion Laboratory, Sunita Verma of Science Systems and Applications Inc., and Steve Howard of Symtech collaborated with the investigators on this project.

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Developing and Validating an Aerosol Model for the Upper Troposphere

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The main purpose of this research was to develop and validate an upper tropospheric aerosol model (UTAM). With this model it is possible to calculate the following quantities: (1) the equilibrium partitioning of various species between the gas and aqueous phases for a wide variety of environmental conditions, (2) the variation in the inorganic aerosol composition as a function of temperature and relative humidity, (3) the solution compositions at which inorganic salt precipitation might occur in upper tropospheric aerosols, and (4) the deliquescence relative humidity (in the atmosphere this is the ambient relative humidity at which a completely dry aerosol becomes thermodynamically unstable and will transform into an aqueous solution droplet) of ammoniated or nitrated aerosols under upper tropospheric conditions. Predicting the equilibrium partitioning has important applications in both gas- and aqueous-phase chemistry modeling calculations, and determining the aerosol composition and salt precipitation can play a significant role in predicting the frequency of cirrus cloud occurrence in the upper troposphere.

Currently, thermodynamic electrolyte models are available for calculating the properties of inorganic aerosols for the conditions found in the lower troposphere and stratosphere. In the lower troposphere, such models are often used in air-quality studies to assess the effects of aerosols on health, gas-phase partitioning, and visibility. In the stratosphere, aerosol models have been used to simulate the formation and growth of polar stratospheric clouds, which are linked to stratospheric ozone depletion. However, these thermodynamic treatments are not suited for calculating the properties of inorganic aerosols under upper tropospheric conditions. Since these aerosols participate in the nucleation and growth of cirrus clouds, understanding their physical properties is crucial for accurately predicting the occurrence of cirrus clouds in the upper troposphere and their subsequent radiative effects.

Simulating the thermodynamic properties of the upper-tropospheric aerosols would require a complex mixed-electrolyte model that accounts for the various ionic interactions in the aqueous solution. This project is developing a mixed-electrolyte model of upper-tropospheric aerosols to address in detail how the current model of cirrus formation from pure sulfuric acid solution droplets can be affected by the presence of ammonium or nitrate ions in solution. Basically, the research shows that ammoniated aerosols are more efficient in nucleating cirrus than are pure sulfuric acid droplets. Further, crude analysis of the recent Subsonic Aircraft: Contrail and Cloud Effects Special Study data indicates that most of the